PRELIMINARY ESTIMATES REPORT

Executive Summary

Purpose and Organization of the Report

Soil in large areas of Washington State contains elevated levels of arsenic and lead that has been caused by a wide range of historical activities. As Washington's population has grown, many of these areas have been developed into residential neighborhoods, schools and parks. These development activities, which continue today, have raised a number of health, environmental and marketplace concerns. The Department's of Agriculture, Ecology, Health and the Office of Community Development believe that a statewide strategy is appropriate for responding to these concerns. The Area-wide Soil Contamination Task Force (Task Force) was formed in January 2002 to advise the four agencies on this issue. The agencies asked the Task Force to issue findings and recommendations on several questions including the question - - "What is currently known about the nature and extent of arsenic and lead soil contamination in Washington State?" This report has been prepared to support the Task Force's deliberations and discussion of this question and includes: (1) a compilation of published information from readily available sources regarding the sources and extent of area-wide arsenic and lead soil contamination in the state, (2) preliminary estimates on the nature and extent of the area-wide soil contamination concerns in Washington State, (3) identification of data gaps identified in developing the preliminary estimates and, (4) recommendations for additional data that should be collected to refine these estimates.

The report is organized into six main sections:

- Introduction: Section 1.0 provides background information and describes the approach used to prepare this report.

- Smelters: Section 2.0 presents information and estimates of elevated soil concentrations associated with past releases from four primary and secondary smelters located in or adjacent to Washington State.

- Arsenical Pesticides: Section 3.0 presents information and estimates of elevated soil concentrations associated with past use of arsenical pesticides.

- Leaded Gasoline: Section 4.0 presents information and estimates on elevated soil concentrations associated with the past use of leaded gasoline.

- Summary and Conclusions: Section 5.0 presents a summary of the preliminary estimates findings and conclusions, identifies data gaps, and provides a summary of recommendations for further data collection and/or evaluation.

- References: Section 6.0 provides a citation of references used in the evaluation and in preparing this report.

The report also includes a series of appendices that include information summaries and maps.

Based on the results of this report, the following general conclusions can be drawn concerning the nature and extent of area-wide contamination in Washington State:

- Elevated levels of arsenic and lead are present in soils in many areas of Washington State from a number of historical sources, primarily metal smelters, lead arsenate pesticides, and emissions from leaded gasoline.

- The precise boundaries of area-wide soil contamination are not defined. However, certain counties have a higher likelihood of elevated levels of arsenic and lead in soil based on their proximity to metal smelters or the estimated use of lead arsenate pesticides during the period from 1900 to 1947.

- Soil concentrations of arsenic and lead in areas impacted by smelter emissions and areas where lead arsenate pesticides were applied to crops are generally higher than those naturally present in Washington soils. However, soil concentrations in these areas are generally lower than those found on the smelter operational sites and areas where lead arsenate pesticides were mixed and formulated.

- Concentrations are highly variable and depend on the historical use and development of individual properties. For example, because of the soil mixing associated with construction, developed properties tend to have lower concentrations of arsenic and lead in soil than undeveloped properties. Because of this variability, concentrations on one property cannot be used to predict concentrations on neighboring properties.

- Additional data could be collected to improve our understanding of the nature and extent of area-wide soil contamination. However, in many instances, a landowner will only be able to verify levels of arsenic and lead in soil by soil sampling. Soil sampling protocols need to be developed for different types of land use needs, and appropriate protective measures identified for landowners who decide not to conduct soil sampling at their property.

Approach Used to Prepare Report

The project scope of work identified a general approach for preparing the preliminary estimates report. This approach was discussed with the Task Force and a technical work group comprised of representatives from state and local government, businesses and contractor staff. The approach for preparing this report was modified based on those discussions and included the following steps:

- Compilation of Available Soil Information: The project team compiled and summarized available data regarding arsenic and lead soil levels associated with area-wide sources of contamination in Washington State.

- Selection of Source Categories: The project team identified several potential sources of area-wide arsenic and lead contamination. These included smelter emissions, past use of arsenical pesticides, use of leaded gasoline, use of fertilizers containing arsenic and/or lead, use of lead-based paint, and use of arsenic treated wood. After a summary of information was presented to the Task Force on these potential sources, the Task Force recommended that further evaluation be limited to smelter emissions, arsenical pesticides, and leaded gasoline.

- Range of Soil Concentrations: The project team reviewed available soil data to identify the range of soil concentrations associated with these sources present in Washington State. In cases where data were limited, as in the case of soils contaminated with pesticides, potential soil concentrations were estimated based on documented application rates. No soil data associated with use of leaded gasoline in Washington State was identified for use in this study. In this case, information from studies completed at other locations, were used to predict potential soil lead concentrations along roadsides as a function of traffic volume.

- Estimates on Extent of Contamination: The potential land area impacted by area-wide sources of contamination was estimated using different methods for each of the sources. In the case of smelter emissions, the extent of land area potentially impacted was estimated based on soil data currently available and predictive modeling of smelter emissions. To estimate the land area potentially impacted by use of arsenical pesticides, the type of crops, application rates, acreage of land under cultivation, and associated time periods of use were identified. In the case of soil impacted by leaded gasoline, no estimate on extent of contamination could be reliably developed because of lack of information on history and traffic volume for most roads in the state. For purpose of comparison, the range of natural background concentrations of arsenic (average concentration of 7 mg/kg statewide) and lead (average concentration of 17 mg/kg statewide) in soil and potentially applicable regulatory concentrations were also presented.

- Identification of Data Gaps and Uncertainties: The extent of area-wide arsenic and lead contamination in Washington is better characterized for some sources than others, but in no case is the extent fully characterized. In some cases, very little data regarding the extent of contamination was found. Large uncertainties are associated with estimates that are provided. These data gaps are identified, and the impact of these data gaps on the reliability of the estimates is discussed.

- Recommendations for Additional Data Collection or Evaluation: Based on the uncertainty associated with preliminary estimates and the inability in many cases to identify specific areas impacted by area-wide sources of contamination, recommendations were made for additional avenues of information collection and evaluation and additional data collection that might improve and refine current estimates.

Elevated Soil Concentrations Associated with Past Smelter Emissions

Smelters historically operated in Washington were located in Tacoma, Everett, and Northport (primary smelters that extract metals from raw ores) and on Harbor Island in Seattle (a secondary smelter that recovered lead from batteries and other sources). A fifth smelter, the Trail smelter located in Trail, British Columbia, just north of the border, operated during most of the last century and continues to operate today. The Trail smelter is near and upwind from the former Northport smelter. These smelters represent area-wide contamination sources because gases and particulates in stack emissions were wind-transported significant distances and deposited on the ground surface. Deposition patterns for each of the smelters vary, and are a function of several factors, including topography, prevailing wind direction and speed, land-water temperature differences, stack height and emission exit velocity, and emitted particle size.

- Range of Soil Concentrations: A broad range of arsenic and lead concentrations have been measured in soils collected from areas around current or former smelter site. For example, arsenic concentrations in areas around the Tacoma Smelter range from natural background levels to over 400 mg/kg for most soil samples, with a few showing arsenic concentrations as high as 3,000 mg/kg. Lead concentrations in most soil samples collected ranged from natural background levels to over 1,000 mg/kg, with some soil samples indicating the presence of lead over 3,000 mg/kg. Soil concentrations in areas around other Washington smelters tend to be somewhat lower because those smelters were operated for shorter periods of time. The general trend from historic smelter stack emissions in Washington appears to be one of the highest concentrations near the smelter and decreasing concentrations with increasing distance in the prevailing wind direction. In all cases, there was significant variability in arsenic and lead levels in soil. Several factors (distance/direction from the smelter, property development and associated soil disturbance (e.g. grading, landscaping), topography, etc) contribute to variations in concentration. Given the significant variability in sample results, arsenic and lead levels found on specific properties may not be reliable indicators of contamination levels on nearby properties.

- Depth of Contamination: Studies performed in areas around the Tacoma Smelter indicate that soil contamination associated with smelter stack emissions tends to be concentrated in the upper 6 to 18 inches of undisturbed soil. This pattern would be expected to be present in undisturbed soils impacted by emissions by the other smelters, and is in fact supported by the more limited soils data associated with the Everett Smelter. However, disturbance due to local land development can significantly affect soil concentrations through processes of dilution or burial. The net effect of these processes around buildings and higher use areas is to decrease concentrations in surface soil and increase concentration variability.

- Extent of Contamination:

  Tacoma Smelter - The estimated land areas impacted by past smelter emissions are summarized in Table E1. Emissions from the Tacoma smelter are estimated to have impacted an area of approximately 240 square miles based on an estimate of where undisturbed soil is likely to exceed the regulatory cleanup level of 20 mg/kg arsenic in shallow soil. An additional 275 square mile area beyond the boundary represents an estimate of where undisturbed soil may occasionally exceed of the regulatory cleanup level of 20 mg/kg will be observed. The potential impact area includes portions of King and Pierce counties. These counties are indicated as counties with high potential for elevated levels of lead and arsenic in soil due to historic smelter emissions, as shown on Figure E1. Additional soil data are currently being collected to better refine the estimate of the impact area for the Tacoma smelter. These data will allow further refinement of the current estimate and provide information on the likely degree of variability of concentrations due to soil disturbance during development.

  Everett Smelter – The impact from the Everett smelter (13 square miles) is estimated to be much smaller than the impact estimated for the Tacoma smelter. The lessor impact area is due to relatively shorter stack height and significantly shorter period of operation associated with the Everett smelter. The potential impact area is limited to Snohomish County, which is indicated as a county with high potential for elevated levels of lead and arsenic in soil due to historic smelter emissions, as shown on Figure E1. However, soil data for the Everett smelter is significantly more limited than Tacoma, and a refined estimate of the impact area cannot be made at this time. Additional data are needed to reduce the uncertainty currently associated with estimates of the Everett smelter impact area.

  Harbor Island Smelter - The area estimated to be impacted by the Harbor Island smelter is less than one square mile, which is the total area of Harbor Island. No data have been collected beyond the perimeter of the island to better refine this estimate, although plume deposition beyond the island perimeter most certainly occurred. Harbor Island is included in King County, which is indicated as a county with high potential for elevated levels of lead and arsenic in soil due to historic smelter emissions, as shown in Figure E1. Some limited modeling was conducted to prepare a mitigation plan for Harbor Island, but this modeling was not extended to predict the limits of impact of historical smelter emissions. Additional modeling and soils data are needed for the Harbor Island smelter to develop a refined estimate of the potential impact area.

Northport/Trail Smelters - Arsenic and lead emissions from the Northport and Trail smelters may also have resulted in significant areas with elevated soil concentrations. Limited soil data is available. However, the area in Washington has been mapped where Trail smelter sulfur dioxide emissions caused injury to vegetation. If metal emissions impacts are assumed to correlate with historical sulfur dioxide impacts, an approximate area of 235 square miles may define soil with elevated arsenic and lead concentrations. Additional data is needed to verify this correlation and quantify the extent of emissions impact on soil. The potential impact area is limited to Stevens County, which is indicated as a county with high potential for elevated levels of lead and arsenic in soil due to historic smelter emissions, as shown on Figure E1.

Elevated Soil Concentrations Associated with Past Use of Arsenical Pesticides

Lead arsenate was the primary arsenical pesticide used in Washington from the early 1900s until about 1947 when it was replaced by new alternatives such as DDT. Lead arsenate was typically used to control chewing insects. Though it was reportedly used on a wide variety of crops, its most extensive use was on apple and pear orchards to control the codling moth. Consequently, the highest accumulated concentrations of lead and arsenic in soil from historical lead arsenate use is expected to be in areas occupied by apple and pear orchards during the first half of the twentieth century. Lead arsenate was applied with increased frequency and in higher potency solutions during this time period because of the increasing resistance of the codling moth. Lead arsenate was used at far lower solution strengths with other crop types and was less frequently applied. Also other crop types changed more frequently relative to apple and pears. Consequently, metals soil concentrations are predicted to be highest associated with historical apple and pear cultivation relative to historical cultivation of other crops.

- <u>Range of Soil Concentrations:</u> Several different sources of information were used to evaluate the impact of historical lead arsenate use. This information included the Bureau of Reclamation Manson area study (initiated in the late 1960s in response to observed problems in replanting former orchard land with new trees), studies completed by the Washington State University (WSU) Tree Fruit Research and Extension Center, and various environmental site investigations completed under Ecology oversight in central and eastern Washington. The Manson study verified that problems associated with establishing trees in old orchard lands was due to residual concentrations of lead and arsenic in soil from use of lead arsenate. Studies completed by WSU of shallow orchard soils indicate residual concentrations of arsenic in soil from background levels to as high as 639 mg/kg, and residual lead concentrations range from background levels to concentrations up to 3200 mg/kg (Peryea and Creger, 1994). Similar concentrations were found during environmental site investigations on land parcels formerly occupied by orchards.

- Depth of Contamination: Studies completed by WSU indicate that high concentrations of lead were limited to shallow soils (5 to 30 cm depth) and decreased sharply with depth. High concentrations of arsenic were detected at slightly greater depths. Most of the lead and arsenic was restricted to the upper 16 inches (40 cm) of soil, and concentrations were lower at the soil surface than deeper in the soil profile. This suggests that both lead and arsenic have leached downward in soil, that the depth of concern due to leaching is relatively shallow, and that arsenic has been preferentially leached relative to lead.

- Extent of Contamination: The estimated land areas impacted by past use of lead arsenate is summarized in Table E1. The acreage of lead arsenate impacted soil was estimated from apple and pear orchard acreage data. Washington State historical agricultural census data was evaluated to estimate the area occupied by apple and pear orchards in the early to mid-1900s. Census data, on the number of apple and pear trees by county in the state is available on 10-year intervals. Using a recommended tree to acre conversion rate, a total estimated land area in each county in Washington State was calculated, and the county totals were added to identify the total land area of the state potentially impacted (187,590 acres or 293 square miles). The counties that contained the highest number of potentially impacted acres are Spokane, Chelan, and Yakima. These counties are indicated as counties with high potential for elevated levels of lead and arsenic in soil due to historic use of arsenical pesticides, as shown on Figure E1. The remaining counties in the state are classified as medium to low potential for elevated levels based on historic use of arsenical pesticides, but may be classified as high potential because of historic smelter emissions. Figure E1 provides a percentage of land area for each county in the state potentially impacted by past use of lead arsenate on apple and pear orchards. This percentage is based on a total county acreage value that excludes publicly owned lands, which were never used for cultivation. It must be noted that the acreage estimate of apple and pear trees is based on the peak year of cultivation acreage, and may overestimate or underestimate the actual number of acres impacted by lead arsenate use. Additionally, the exact location of the impacted land could not be determined based on available information.

Elevated Soil Concentrations Associated with Past Use of Leaded Gasoline

Leaded gasoline was identified as a potential source of area-wide soil contamination, due to deposition of lead from internal combustion engine exhaust. Gasoline with added tetraethyl lead was used in the United States from about 1923 until the mid-1970s. During this time period, approximately 75% of the lead in the gasoline were discharged into the environment through vehicle exhaust. Numerous studies have been completed that evaluated concentrations of lead in roadside soil, water, and ecological receptors as a result of use of leaded gasoline. Based on these studies, a model was identified that predicted roadside soil lead concentration based on traffic volume. This model was used with historical traffic volume information for major roads and highways in Washington to predict the roadside lead concentration in soil associated with different traffic volumes over various time periods.

- <u>Range of Soil Concentrations:</u> Using the identified model for predicting soil lead concentrations adjacent to Washington roads based on traffic volume, estimates of potential concentrations of lead in soil adjacent to roads could be made. For example, using the model and assuming a traffic volume of 0 to 999 vehicles per day for a 20-year period would predict a maximum roadside lead soil concentration of 342 mg/kg. A traffic volume of greater than 80,000 vehicles per day for a 60-year period could result in a roadside lead concentration in soil of greater than 1,423 mg/kg. Soil data were not available in Washington State to validate the soil lead concentrations predicted by this model.

- <u>Depth of Contamination:</u> Researchers generally reported that most of the soil lead contamination associated with past use of leaded gasoline is limited to the top 15 to 20 cm of soil. However, they also found that lead concentrations from this source could be higher in soil below the surface if sources in the past exceeded those of the present or if downward migration has occurred.

- Extent of Contamination: The area of land potentially impacted by past use of leaded gasoline could not be estimated. Studies completed at other locations indicate that most of the lead emitted from vehicles accumulated in soil within 15-20 m (50 to 60 ft) from the roadside. However, the total land area potentially impacted could not be estimated because lifetime and historical traffic volume information is not available on most roads in Washington State. Washington Department of Transportation traffic volume information was only available for major roads and highways, which represent only a fraction of the total road miles in the state and are not representative of areas where most contact with soil adjacent to road, such as in residential areas, is likely to occur. Therefore, the predicted soil lead concentrations are not necessarily applicable to most of the state roads. Some correlations might be drawn if road use history and traffic volume information were available for these other roads; however, the information would have to be obtained on a local (county or city) level, since this information is not maintained at the state level. Additionally, actual soil data would need to be collected from representative roadsides to validate predictions made by the model used to estimate roadside lead soil concentrations.

Summary

In summary, the extent of contamination and range of concentration values is not well known for most of the sources identified and evaluated in this study. Although some predictions can be made with respect to the concentration of lead and arsenic that may be present in soil as a result of these sources, these predictions have a relatively high degree of associated uncertainty. Additional information and soil data should be collected to develop better estimates. In some cases, additional data is already being collected.

With respect to the smelter emissions as a soil contaminant source, the following data gaps and recommendations were identified:

- Additional data is currently being collected downwind of the Tacoma smelter plume. These data will be used to further refine the potential area of impact from historic emissions associated with the Tacoma smelter. This data, in addition to other soil data collected and the emission modeling that has been conducted, should allow for an reasonably accurate estimate of area of impact and degree of variability that is associated with the data. No critical remaining data gaps were identified, and no additional data collection is recommended at this time.

- The extent of soil contamination from the Everett, Harbor Island, and Northport smelters has not yet been determined, and additional data is needed to identify the potential extent of impact from emissions from these sources. Prior to designing soil sampling plans, emission modeling should be conducted to help inform data collection. Emission modeling should also be conducted after collection of additional soil data to validate the predictive modeling. These soil sampling studies should be collected in a phased manner to allow for maximizing cost effectiveness of the sampling effort by building on results obtained in earlier sampling phases. The purpose and objectives of the soil sampling effort must be clearly defined at the onset of the project so that the sampling design can meet the defined objectives. Soil sampling studies should be designed to define the extent of the area impacted by the historic emissions and to identify the degree of variability of the data due to emission deposition patterns and land disturbance.

With respect to lead arsenate as a source of soil contamination, the following data gaps and recommendations were identified:

- An accurate estimation of the area of land potentially impacted by use of lead arsenate pesticide or levels of lead and arsenic in soil on these lands cannot be made. The exact location of all apple and pear orchards that received lead arsenate during the early to mid-1900s cannot be determined, and the total amount of lead arsenate applied to any given orchard will not be known.

- An inventory of information that may be available at the local (city and county) level that may assist in identifying whether land was formerly occupied by apple or pear orchards should be developed, and sources of this information identified. These sources of information may reveal whether a particular parcel of land was apple or pear orchard at one time. It is recommended that if this inventory of information indicates a particular source or sources of information that can identify past land use as orchard land, that a soil sampling program be initiated to test how well these sources of information predict past use as an orchard. It should be noted that even if a relatively reliable source of information that indicates past land use as orchard land is identified, a landowner would only be able to verify levels of arsenic and lead in soil by soil sampling. It is recommended that a soil sampling protocol that can be used by landowners be developed to verify soil conditions. If the landowner elects not to verify soil conditions, it is recommended that protective measures be identified that the landowner can implement to minimize risk.

- Absence of specific information indication that a particular parcel was used as an orchard in the past will not exclude the parcel from the possibility that apple or pear orchards once occupied the property. In these cases, a landowner will only be able to verify levels of arsenic and lead in soil by soil sampling. It is recommended that a soil sampling protocol that can be used by landowners be developed to verify soil conditions. If the landowner elects not to verify soil conditions, it is recommended that protective measures be identified that the landowner can implement to minimize risk.

- It is recommended that the soil sampling protocol developed to be used by landowners to verify soil conditions and the protective measures identified for the landowners use should be linked to specific types of types of land use conditions.

With respect to use of leaded gasoline as a source of soil contamination, the following data gaps and recommendations were identified:

- No studies were located pertaining to lead concentration in soil along roadsides as a result of leaded gas use in Washington State. Absence of soil data to validate roadside lead concentrations predicted by the model is a significant data gap.

- An accurate estimation of the area of land potentially impacted by use of leaded gasoline or the level of lead likely to be found in soil cannot be made. A rough prediction can be made of lead levels that may be found in roadside soils, but this prediction is dependent on the life history of the road and historic traffic volumes. The prediction presented in the report is based on high traffic roads, and no Washington State data were available to verify the predicted concentrations.

- Some correlations may be made using the results of the model based on high traffic volume roads to predict impacts adjacent to lower traffic volume roads, but estimates made are likely to have a high level of associated uncertainty. Local governments (city and county) should be consulted to determine if specific information on low traffic roads (road age, traffic volume history) is available to perform these correlations. However, the validity of these correlations cannot be determined without data collected from representative Washington State roads to verify the lead concentrations in roadside soil predicted by the model.

- It is recommended that Washington State data be collected to test the validity of the predictive modeling conducted in this report. Such a study should include a sufficient cross section of representative roads in the state to both verify soil lead concentrations predictions made for high traffic roads, and to determine if correlations can be made with lower volume traffic roads for predicting soil lead concentrations along roads not classified as highways or major arterial roads in the state. It should be noted that even if a reliable model is identified and verified based on Washington State soil data, a landowner would only be able to verify levels of lead in soil by soil sampling. It is recommended that a soil sampling protocol that can be used by landowners be developed to verify soil conditions. If the landowner elects not to verify soil conditions, it is recommended that protective measures be identified that the landowner can implement to minimize risk.

- It is recommended that the soil sampling protocol developed to be used by landowners to verify soil conditions and the protective measures identified for the landowners use should be linked to specific types of types of land use conditions.

Table E1
Preliminary Estimates Summary

Department of Ecology
Area-wide Contamination Strategy Project

Source	Estimated Land Area Impacted
Smelters	
Tacoma	515 square miles
Everett	13 square miles (1) (2)
Harbor Island	< 1 square mile (1)
Northport and Trail	235 square miles (1) (2)
Orchard Land	187,590 acres (approximately 292 square miles)
Roadsides	Cannot be estimated

(1) Extent of impacted area has not been fully characterized.
(2) Based on air modeling for Everett and maps of sulfur dioxide injury to vegetations for Northport and Trail.

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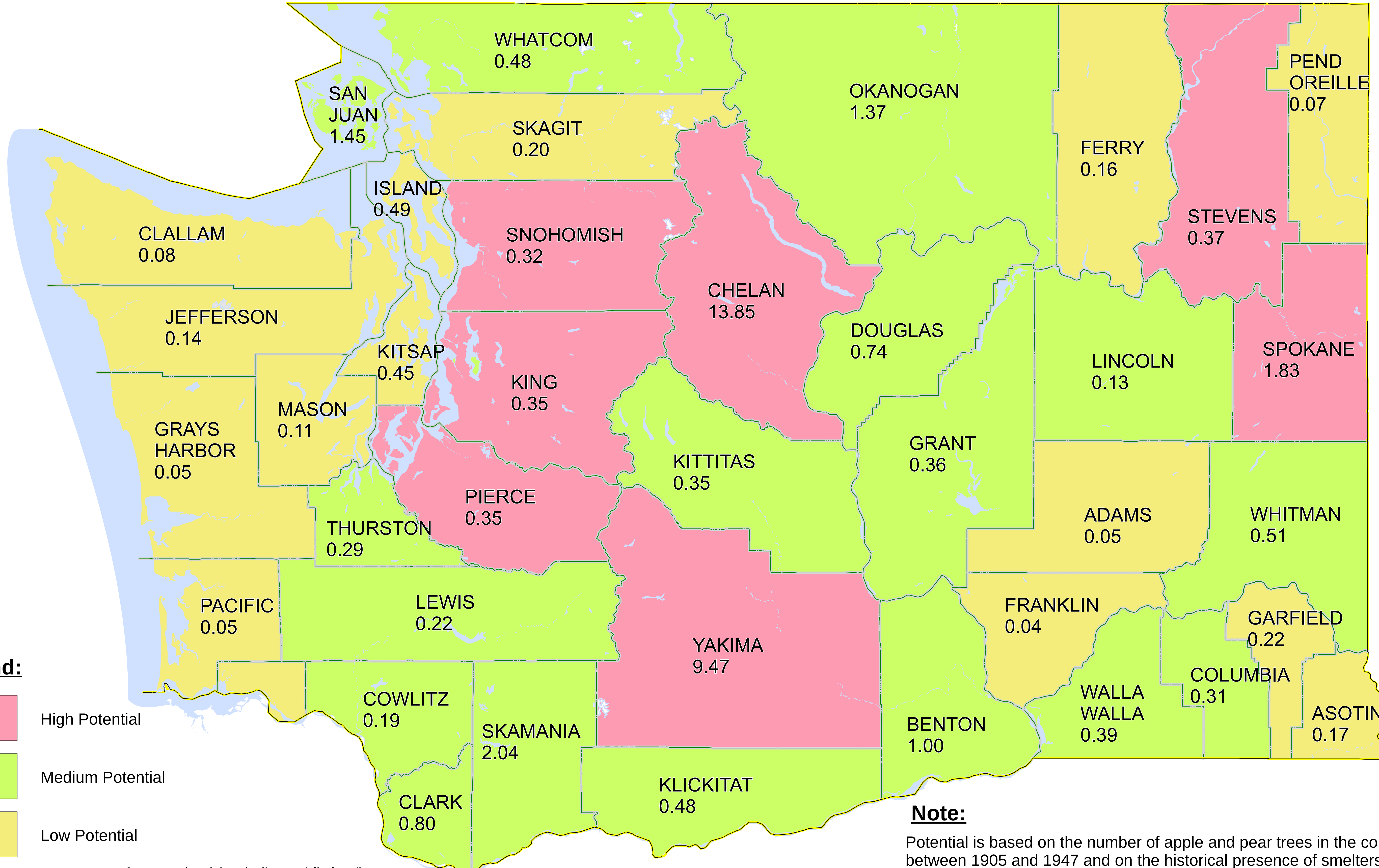

Legend:

High Potential

Medium Potential

Low Potential

0.16 Percentage of County land (excluding public land) potentially impacted by past use of lead arsenate pesticide on apple and pear orchards

Note:

Potential is based on the number of apple and pear trees in the county between 1905 and 1947 and on the historical presence of smelters

Washington State Dept. of Ecology Area-Wide Contamination Strategy Project	**Potential for Elevated Levels of Arsenic and Lead in Soil from Area-Wide Contamination Source**	Figure E1

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Ecology/Strategy Project/Tech Memo | T:\1380\003\210\FigE1.cdr 10/24/2002